TC-21

IMPACTO DEL AMBIENTE TROPICAL EN LA DURABILIDAD DEL CONCRETO ARMADO: PROYECTO DURACON

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INTRODUCTION

Reinforcement corrosion is one of the most common causes of deterioration in reinforced-concrete structures, leading to high maintenance and repair costs. There has been extensive research on reinforcement corrosion for the past fifteen years, but with special focus on 1) studying the causes and mechanisms of deterioration, 2) developing electrochemical techniques for evaluating and controlling deterioration (both in-lab and *in situ*), and 3) employing protection methods designed to impede the onset of deterioration. More recently, the need was felt for quantifying the useful life of structures affected by corrosion, so research has been directed towards finding models that would enable engineers to predict the useful life of non-deteriorated in-service structures or, if new, to estimate their future life, getting involved since the project phase. One of the most common causes of reinforcement corrosion is the ingress of chloride ions through the concrete-pore network when the concrete is located in marine environments. Chloride ions can cause localized corrosion of the reinforcement and, therefore, produce premature and unexpected structural failure. Chloride penetration may occur either by diffusion in water-saturated concrete or due to absorption/desorption phenomena throughout humidity/drying condition cyclic exposure. These cycles produce faster chloride-ion ingress mechanisms because, besides diffusion, capillary absorption or saline mist phenomena also induce higher moisture diffusivity. When making predictions, Fick's Second Law is the one most currently used for finding the diffusion coefficient - D - both in real and laboratory structures. However, more and more data consistently reveal the limitations of this equation ——especially manifest in the scant and limited relationship found between laboratory and real-life structures[1-3]

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[TC-21] 1

With regard to the limit of chlorides that could produce depassivation of the reinforcement, either 0.4% in cement weight[4] is accepted as the limit value in the water used for mixing the concrete or a ratio of $Cl^-/OH^- = 0.6$ if it is a case of chlorides penetrating from the outside. However, recent studies[5-9] on mortar and concrete has questioned these values because they have always found higher thresholds, ranging from 1%-2% chlorides with regard to cement weight and from 2 to 8 for the Cl^-/OH^- ratio. From the few studies carried out, a great amount of scattering can be seen, even under apparently identical conditions. Several factors have been identified as indicating that there is no single chloride threshold value that produces reinforcement depassivation: 1) Cement type and content, 2) condition of steel surface, 3) porosity of the concrete, 4) temperature, 4) Cl^- penetration rate (aggregates, penetration), 5) prevailing meteorochemical conditions in the surrounding area, among others. Some of these factors are very difficult to control in isolation, which ultimately entails that the study should be carried out through statistical treatments that would allow a definition of the variation ranges in accordance with one of the factors described above. Therefore, as already indicated, both problems are directly related to the meteorochemical parameters of the environment to which the structures are exposed. In Iberoamerica[10], there is a very great diversity of climates/microclimates that would allow a more accurate definition of these chloride-ion levels and of the carbonation that causes reinforcement corrosion. As a result, in 2000 CYTED (Science and Technology for Development Program, Spain), approved the DURACON project "The Influence of Environmental Action on Reinforced Concrete Durability" (within the XV Subprogram (SP XV) "Corrosion and Environmental Impact on Materials") in which 10 countries are participating: Argentina, Bolivia, Chile, Colombia, Costa Rica, Spain, Mexico, Uruguay, Portugal and Venezuela. The aim of this project is to characterize the durability of concrete exposed to prevailing environmental conditions in Iberoamerica. This paper presents the results obtained after more than two-year evaluation in some of the marine and urban environments.

EXPERIMENTAL PROCEDURE

Preparation and Characterization of Concrete Mixes.- Concrete mixes with w/c ratio of 0.45 and 0.65 were prepared. The following tests were performed to characterize the concrete mixes physically and mechanically, in each country involved: Compressive strength at 28 and 90 days (ASTM Standard C 39); Indirect Resistance to Stress at 28 days (ASTM Standard C 496); Modulus of Elasticity at 28 days (ASTM Standard C 469); Resistivity (in saturated specimen/Manual DURAR[4]); Total Absorption and Total Porosity (ASTM Standard C 642); Capillary Absorption (Fagerlund Technique)[11]; Rapid Chloride Permeability (ASTM C 1202), all of them at 28 days of curing. These tests were performed using 15x30 cm cylinders cast at the same time the prisms were prepared. Six concrete prisms, 15x15x30 cm, were placed in each exposing site. Three were plain, non reinforced concrete prisms, and the remaining three were reinforced with six rebars (9.5 mm in diameter). The rebars were placed into the prisms to obtain concrete covers of 15, 20 and 30 mm. Figure 1 shows the geometry of the concrete prisms used in this investigation and a typical test site in which the different test specimens are on display. The non-reinforced prisms were used for carrying out different tests on the concrete, such as carbonation front, chloride concentration profiles, and electrical resistivity under water-saturation conditions. The reinforced prisms were used for electrochemical tests such as half-cell potentials, corrosion rate, and the electrical resistivity of the concrete.

Environmental Parameter Tests.- Evaluation of the climatic and environmental parameters in each of the exposure sites during the test period was based on the methodology established by ISO Standard 9233[12] for classifying atmospheric aggressiveness. The most important parameters used in this investigation to classify the environments were environmental humidity, time of wetness (TOW/т**),** chloride concentration, sulfate concentration, wind speed and direction, pluvial precipitation, temperature, and CO_2 concentration. In most of the cases, this meteorological and chemical evaluation of the environment's exposure sites was determined every month.

Corrosion Parameters Tests.- The evaluation of half-cell potential (E_{corr}), corrosion rate (i_{corr}) and electrical resistivity of the concrete (ρ) were determined monthly, using the reinforced prisms. The corrosion rate was measured by the polarization-resistance

technique[13]. The specimens were set up with one of the 15x30 cm faces toward the prevailing winds and the other in the opposite direction (Figure 1). The electrochemical evaluation was carried out on both faces. The cast face of the prism, showing the higher porous content, was placed downwards to avoid preferential ingress of aggressive agents from the environment.

Chemical Tests On the Non-reinforced Concrete Prisms.- Chemical alteration of the concrete due to its exposure to the environment was determined using the non-reinforced prisms, analyzing them yearly or earlier, if any of the rebars in at least two prisms became activated. A 5-cm thick specimen from each of the non-reinforced concrete prisms was cut using a special custom-made device (guillotine)[14,15]. The new, freshly cut face of the prism was then protected with epoxy paint. The carbonation front was measured on the freshly broken face of specimens (15x15 cm) using a wet pH indicator, as explained elsewhere[4]. The chloride concentration analysis was performed using two 2.5-cm $\varnothing$ cores extracted from the center of the cut specimen , located 3 cm from the border of the slice. The cores were sliced, crushed and powdered to perform an acid-based chloride extraction, to obtain the total chloride concentration, and a water-based chloride extraction to obtain the unbound (free) chloride concentration[4].

RESULTS AND DISCUSSION

Physical-mechanical Characterization of the Concrete Used in Each Country.-
Tables 1 and 2 show the physical characterization of the different types of concrete prepared in each country of this project. It must be noted that, although an attempt was made to use the same Portland cement and aggregate type, the final characteristics of the concrete were different in each country, which may affect concrete quality, both from the mechanical and durability standpoints[16].

Characterization of the Exposure Environments.- ISO Standard 9223[12] classifies the atmosphere in accordance with TOW and the deposition rate of atmospheric pollutants: sulfur compounds (P) and salinity (S). Figure 2 attempts to show the expected relative aggressiveness at the different test sites analyzed. However, considering that, unlike carbon dioxide and chloride ions, the sulfur dioxide (SO_2) content in the atmosphere does not affect

significantly the reinforcement corrosion, CO_2 instead of SO_2 content is plotted as the "Y" axis in Figure 2. This Figure shows the results from most of the marine and urban test sites, which have so far undergone evaluation for one year. Notice the wide range of environments, from moderate to very high corrosivity, taking Chlorides and CO_2 concentration in the atmosphere into consideration for the particular case of the concrete types exposed to the marine and urban atmospheres. Table 3 and 4 also show the meteorological and chemical variables yearly averages and the ISO 9223 classification for the marine and urban environments, respectively, in some of the test sites that have undergone one year of evaluation.

Analysis of corrosion potentiality and probability, and the electrochemical evaluation in the different exposure environments. Based on the characterization of concrete properties and the environment aggressiveness (Tables 1 - 4), a preliminary estimation of the potentiality and probability of reinforcement corrosion can be performed. These results were analyzed in a paper published recently[16]. Following, the most important results are presented proving that this analysis was adequate. Such analysis was performed by comparing data from the corrosion potentiality and probability analysis and the corrosion activity of the embedded steel on each testing sites based on electrochemical techniques.

Marine Atmosphere.- In order to determine reinforcement corrosion probability in the marine environment, the potentiality of the environment must be analyzed jointly with those of the prepared concrete mixtures. Table 3 presents, from left to right, the order in which the reinforcement corrosion potentiality, based on ISO Standard 9223 environment aggressiveness, is greater. The order was obtained based on chloride ion content only. Notice that the TOW ($>\tau_3$) is similar in all marine sites presented in this work. From the results summarized in Table 1, which also shows the characterization of the different types of concrete evaluated (w/c = 0.45) in the different countries, it can be seen that, even though the Portugal concrete is of good quality, the reinforcement would have the greatest probability of corrosion in this concrete given that this environment has a high chloride-ion concentration (1392 mg/m^{2}d).

In the cases of La Voz in Venezuela and Vigo in Spain, with similar environment corrosivity, even though the Venezuelan cement has a greater C_3A content (10% in comparison with 0.4% for Spain), it is the worst quality concrete because, besides having the lowest compressive strength, it has a high effective porosity (>7%) and capillary absorption (0.0082 kg m^{-2} s$^{-1/2}$). Therefore, it is expected that La Voz will be in the second place for reinforcement corrosion occurrence probability, followed by Vigo in Spain. Other environmental effects would be considered mainly the average annual temperature and precipitation for corrosion propagation. Venezuela shows the highest average annual temperature which will increase chloride-ion diffusion through the concrete. Although this effect is also observed in Colombia, the chloride content in the Buenaventura atmosphere is low compared with the La Voz test station; besides, in Buenaventura it rains almost all year, which would constantly wash the chlorides from the concrete surface, thereby diminishing chloride penetration into concrete. Therefore, the greatest-to-least expected reinforcement corrosion probability for the two concrete mixes will be: Cabo Raso/Portugal > La Voz/Venezuela >Vigo/Spain > Buenaventura/Colombia > Valparaiso/Chile.

Corrosion Parameters Evaluation.- In the present case, information will be given only on countries showing reinforcement corrosion activity before two years have elapsed, so as to compare them with the prediction of the probability of reinforcement corrosion based on the concrete characterization and the aggressiveness of the environment in the different countries. Figure 3 shows the reinforcement potentials and corrosion rates after two years of exposure for concrete with w/c ratio = 0.65 exposed in Cabo Raso (Portugal) and La Voz (Venezuela). Note that for Cabo Raso the rebars begin to corrode after only 10 months of exposure. La Voz is second in aggressiveness, since the rebars at 15 mm, on the face exposed to the prevailing winds, became activated after 22 months of exposure. These results are in agreement with the prediction based on the potentiality/probability reinforcement corrosion analysis carried out (Tables 1 - 4). For concrete mix with w/c ratio = 0.45; so far, no depassivation occurred at the rebars.

Figure 3 indicates an excellent accordance between the corrosion rate and potential evolution, which enables a clear identification of the moment at which the reinforcement is activated (E_{corr} < - 250 mV vs. Cu/CuSO$_4$ and i_{corr} > 0.1 µA/cm^2).

Table 5 sumarizes the free chloride threshold concentration and the depth at which the rebar is depassivated for the first two years of exposure at Cabo Raso and La Voz test sites for the w/c = 0.65 concrete. As shown in Table 3 for Cabo Raso, the higher free chloride concentrations in the concrete might be due to the high chloride contamination in the environment (1392.0 mg/m^{2}d) as compared with La Voz site (166.5 mg/m^{2}d). However, it is important to note that the chloride threshold concentration for 15 mm depth reinforcement depassivation was lower in La Voz (0.4% vs. 0.89%), and the diffusion coefficient was three times higher (37,95 x10^{-12}m^2/s vs. 10.09 x10^{-12}m^2/s in Cabo Raso). This might be due to the lower quality concrete used in La Voz (fc$_k$ = 26.80 MPa, k = 0.025 kg m^{-2} s$^{-1/2}$), its higher environment temperature (29.35 °C vs. 17.0 °C in Cabo Raso), and the higher time of wetness (0.67 vs. 0.46 in Cabo Raso), which increased the diffusion rate of such chloride ions into the concrete. Lower chloride threshold concentration was obtained for 20 mm depth rebar in both test sites (0.68 % in Cabo Raso and 0.3 % in La Voz). This might be due to higher concrete humidity at those rebar depths, where the oxygen availability is still sufficient. At lesser depths the rebar corrosion (in the form of pits), is determined by the humidity content into the concrete, i.e., its resistivity, which depends on its chloride-ion content. On the other hand, the concrete remains more humid at greater depths, thus restricting oxygen access (diffusion control) in such a way that less chloride-ion concentration could induce the rupture of the passive film. Although oxygen is needed to maintain rebar corrosion, it is also required to keep the rebar passive.

Taking into consideration that only two out of twenty one marine test sites are presented in this paper, further evaluation is needed regarding chloride levels for rebar depassivation, depending on the environmental factors surrounding the reinforced concrete as well as the particular characteristics of each concrete mix.

Urban Atmospheres.- In these environments, only the probability of corrosion by carbonation will be analyzed for concrete with w/c = 0.65 (Table 2) since, as it is well known for good quality concrete, such as those prepared with w/c = 0.45 (Table 1), there is a very low potentiality and probability of reinforcement corrosion by carbonation.

Table 2 shows that the concrete prepared in Chile is the one with the highest reinforcement corrosion potentiality for the 0.65 w/c ratio mixtures. It is not the one with the lowest

compressive strength, but it has the highest absorption (0,0341 kg m^{-2} s$^{-1/2}$), and highest effective porosity (16,1%). Venezuela's is the one with the second highest potentiality. On the other hand, the concrete prepared in Portugal shows the best quality of all because, even though it does not have the greatest compressive strength, it has the least capillary absorption.

Table 4 shows the different parameters (yearly averages) that would enable the aggressiveness of the environment to be evaluated from the CO_2 content standpoint[16]. Relative humidity is very important for faster carbonation, but above all the TOW fraction, by means of which the percentage of time a naked plate would remain wet during one year (>0ºC, >80%RH) is more important for faster corrosion.

Table 4 presents the average annual values of the factors that are most likely to affect CO_2 ingress into the concrete. In accordance with CO_2 content in the atmosphere, the most aggressive would be the environment at the Chihuahua test site in Mexico, followed closely by the test sites in Santiago, Chile, and La Paz, Bolivia. However, in this case, one must also consider that CO_2 ingress into the concrete requires low relative humidity (<80%). All the test sites under study have average RH lower than 80%, being the most propitious for faster carbonation (RH~60%), the Santiago test site. When the characteristics of the concrete (cement content and effective porosity, Table 2) are evaluated together with the environmental parameters (CO_2 content and relative humidity, Table 4), it can be seen that the Santiago test site in Chile has the most potentially aggressive combination of environment (1.4 mg/L of CO_2 with 61.2 % of Relative Humidity), and concrete properties (16.1 % of effective porosity and water absorption = 0.0341 kg/m^2 s$^{1/2}$) for faster carbonation of the ones analyzed so far. The order of aggressiveness (greatest to least) would be: Santiago/Chile > La Paz/Bolivia > Maracaibo/Venezuela > Merida/Mexico > Tarabana /Venezuela > Chihuahua/Mexico > Madrid/Spain > Prado/Uruguay > Cali(1)/Colombia > Lisbon/Portugal > Cali(2)/Colombia.

Nevertheless, once the concrete is carbonated, RH should be >80% to have active reinforcement corrosion. So, the time of wetness fraction (f(τ) which is the percentage of time a naked plate would remain wet during one year; at >0ºC and >80% RH) might be used as an important parameter to indicate carbonation-induced corrosion. In Santiago, this parameter

is very low (11%), which would indicate that, even though it is the most easily carbonated concrete; the environment has not enough moisture to initially induce reinforcement corrosion. On the other hand, the Tarabana test site in Venezuela is the one with the greatest TOW fraction, followed by the Merida test site in Mexico and the Lisbon test site in Portugal; but if the concrete is too wet it will be difficult for CO_2 to further diffuse into the concrete. When the concrete properties (effective porosity, Table 2) are taken into account with the environment (T, Rain, RH and TOW, Table 3), the most potentially aggressive combination of environment and concrete properties for higher corrosion rates on carbonated concrete would be (highest to lowest): Maracaibo/Venezuela > Merida/Mexico > Tarabana/Venezuela > Lisbon/Portugal > Santiago/Chile > Madrid/Spain > La Paz/Bolivia, Chihuahua/Mexico > Cali(1)/Colombia > Cali(2)/Colombia.

Concrete Carbonation Evaluation and Corrosion Parameter Tests.- In the present case, information will be given only on countries after two years exposure, so as to compare them with the prediction of the probability of carbonation based on concrete physical characterization and the environment aggressiveness in the different countries. Table 6 shows the carbonation depth from the specimens with w/c = 0,65 after two years of exposure, except for the test sites at Merida, Uruguay and Madrid that are results from only one year of exposure. From greatest to lowest the order for the exposed face is: La Paz/Bolivia > Santiago/Chile > Maracaibo/Venezuela > Chihuahua/Mexico > Tarabana/Venezuela > Merida/Mexico > Lisbon/Portugal > > Prado/Uruguay > Cali(1)/Colombia > Cali(2)/Colombia > Madrid/Spain. Based on the carbonation coefficients, corrosion activity should be observed in the Bolivia and Santiago specimens after 2.5 and 3 years of testing, respectively. Next would be in the Maracaibo and the Chihuahua specimens after only 4.2 and 4.5 years, respectively. For the specimens at Tarabana, Merida and Lisbon, corrosion activity is expected after 10, 12 and 13 years of exposure, respectively.These results are in partial agreement with the prediction based on the potentiality/probability concrete carbonation analysis carried out. No complete agreement was expected as the prediction was based on the environment aggressiveness information of the first year and the data may have changed from one year to the other.

Figure 4 shows the electrochemical evaluation after more than two years of exposure in the test sites at Maracaibo, Santiago, and La Paz, where it is observed than only in Maracaibo the rebar with 15 mm of concrete cover is already active, whereas in Santiago and La Paz is still passive, in accordance with the potentiality and probability of reinforcement corrosion analysis performed.

CONCLUSIONS

The test sites and the results presented only represent their specific microclimates. Therefore, one must be careful when extrapolating these results to avoid confusion or misunderstanding regarding the corrosivity of reinforced concrete. The following conclusions may be drawn from the results reported so far in the study:

- To determine the probability of reinforcement corrosion under specific environmental conditions, a joint analysis of the potentiality of the exposure environment corrosivity and the concrete quality must be carried out.
- In marine atmospheres, chloride content in the environment is a decisive factor when evaluating the probability of reinforcement corrosion.
- In urban atmospheres, concrete quality, CO_2 content and the TOW fraction ($f(\tau)$) are the most important factors to be considered when evaluating the probability of rebar corrosion.
- The results after two years of exposure show clear differences among the different types of reinforced concrete exposed to specific microclimates. The values of critical chloride content are influenced by TOW factor and temperature conditions.
- Potentiality and probability analyses for reinforcement corrosion based on the concrete mixes characteristics and the specific environment of exposure are in accordance with the results from electrochemical measurements.

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Table 1. Concrete properties for W/C = 0,45 mixtures.

COUNTRY	BOLIVIA	CHILE	COLOMBIA	MEXICO	PORTUGAL	SPAIN	URUGUAY	VENEZUELA
fc_k (MPa)/28 days	26.63	43.6	52.3/62.0	51.5	63.9	43.2	44.3	33,8
m (s/m^2)	3.21×10^7	2.50×10^7	$15.26/10.70 \times 10^7$	3.48×10^7	-	10.5×10^7	3.3×10^7	8.68×10^7
k (kg/m^2 s$^{1/2}$)	0.0054	0.0027	0.0060/0.0066	0.0147	0.0020	0.0054	0.0052	0.0082
ε (%)	-	1.4	7.4/6.8	8.7	-	5.5	11.2	7.6
Cement Content (kg/m^3)	400	387	400	411	400	400	400	414

Table 2. Concrete properties for W/C = 0,65 mixtures.

COUNTRY	BOLIVIA	CHILE	COLOMBIA	MEXICO	PORTUGAL	SPAIN	URUGUAY	VENEZUELA
fc_k (MPa)/28 days	16.81	19.,8	28.0/36.1	40.0	35.4	27.0	28.4	26.8
m (s/m^2)	2.12×10^7	2.25×10^7	$7.28/4.50 \times 10^7$	3.60×10^7	-	6.1×10^7	3.2×10^7	3.71×10^7
k (kg/m^2 s$^{1/2}$)	0.0202	0.0341	0.0122/0.0085	0.0199	0.0069	0.0091	0.0065	0.0250
ε (%)	-	16.1	10.4/5.7	11.9	-	7.1	15.0	15.2
Cement Content (kg/m^3)	320	323	306/335	285	260	300	323	355

Table 3. Potential and probability of reinforcement corrosion onset by chlorides difussion.

COUNTRY (Station)		PORTUGAL Cabo Raso	VENEZUELA La Voz	SPAIN Vigo	COLOMBIA Buenaventura	CHILE Valparaíso
Environment (yearly Average)	RH (%)	74.0	90.0	69.0	89.2	82.8
	TOW (f(τ))	0.46	0.67	0.31	0.89	0.70
	Temp. (ºC)	17.0	29.4	15.8	25.9	15.3
	CO_2 (mg/L)	1392.0	166.5	156.2	29.0	19.3
	Rain (mm/year)	109	398	1268	6581	500

Table 4. Potential and probability of reinforcement corrosion onset by carbonation.

COUNTRY (Station)		BOLIVIA La Paz	CHILE Santiago	COLOMBIA Cali	MEXICO Merida/ Chihuahua	PORTUGAL Lisboa	SPAIN Madrid	URUGUAY Prado	VENEZUELA Maracaibo/ Tarabana
Environment (yearly Average)	RH (%)	49.46	61.2	69.3	72.8/32.9	74.5	62.8	72.7	72.5/81.4
	TOW (f(τ))	0.20	0.11	0.104	0.44/0.05	0.43	0.20	-	0.28/0.59
	Temp. (ºC)	12.08	16.8	25.2	25.1/19,9	16.1	14.6	16.3	28.6/24.1
	CO_2 (mg/L)	1.09	1.40	0.60	0.90/1.48	0.71	0.91	0.8	0.78/0.91
	Rain (mm/year)	505.3	992	1222	896/272	936	362	1771.7	347/796

Table 5. results of the rebars that have undergone depassivation after two years' exposure to the marine environments of la Voz, Venezuela, and Cabo Raso, Portugal.

Station	Mixture	D_{ap} (10⁻¹²) (m²/s)	Probe	i_{corr}* > 0.1 µA/cm²	E_{corr}* Cu/CuSO₄ < -250 mV	Time† to initiate depassivation (months)	Free Cl⁻ ‡ (%)
La Voz	0.65 Exposed face	37.95	1	15	15	22	0.42
			2	15	15	22	0.42
			3	15	15	22	0.42
				20	20	20	0.30
	0.65 Non-exposed face	42.07	1	15	15	20	0.48
			2	-	-	-	-
			3	-	-	-	-
Cabo Raso	0.65 Exposed face	10.09	1	15	15	10	0.89
				20	20	-	-
			2	15	15	10	0.89
				20	20	11	0.68
			3	15	15	10	0.89
				20	20	11	0.68
	0.65 Non-exposed face	7.23	1	15	15	11	0.76
				20	20	13	0.57
			2	15	15	13	0.76
				20	-	-	-
			3	15	15	11	0.76
				20	-	-	-

* Rebars depassivated

† Taken from Figure 3, when E_{corr} is ≤ - 250 mV and i_{corr} is ≥ 0,1 µA/cm²

‡ Average Free Chlorides which produces depassivation (La Voz/taken at the same time the rebar depassivated; Cabo Raso/estimated by using Fick's second law)

Table 6. Average carbonation depth from concrete specimens with W/C = 0. 65 after two years of exposure.

	Exposed Face		Non-exposed Face	
	eCO_2 (mm)	K (mm/y$^{1/2}$)	eCO_2 (mm)	K (mm/y$^{1/2}$)
BOLIVIA La Paz[††]	12.46	9.4	11.39	8.63
COLOMBIA Cali	3.70/4.50	2.6/3.2	4.50/4.60	3.1/3.3
CHILE Santiago	11.50	8.5	10.50	7.8
MEXICO Merida[†]	4.60	4.3	3.40	3.2
Chihuahua	10.01	7.1	7.73	5.5
PORTUGAL Lisbon	6.48	3.5	8.18	4.1
SPAIN Madrid[†]	1.60	1.6	1.60	1.6
URUGUAY Prado[†]	3.0	3.0	1.0	1.0
VENEZUELA Maracaibo	10.33	7.3	10.00	7.1
Tarabana	6.78	4.8	7.44	5.3
[†]One year exposure [††]Twenty one months exposure				

Figure 1.- Left: Typical Marine Test Station. Right: Sketch of the prismatic specimen for electrochemical measurements
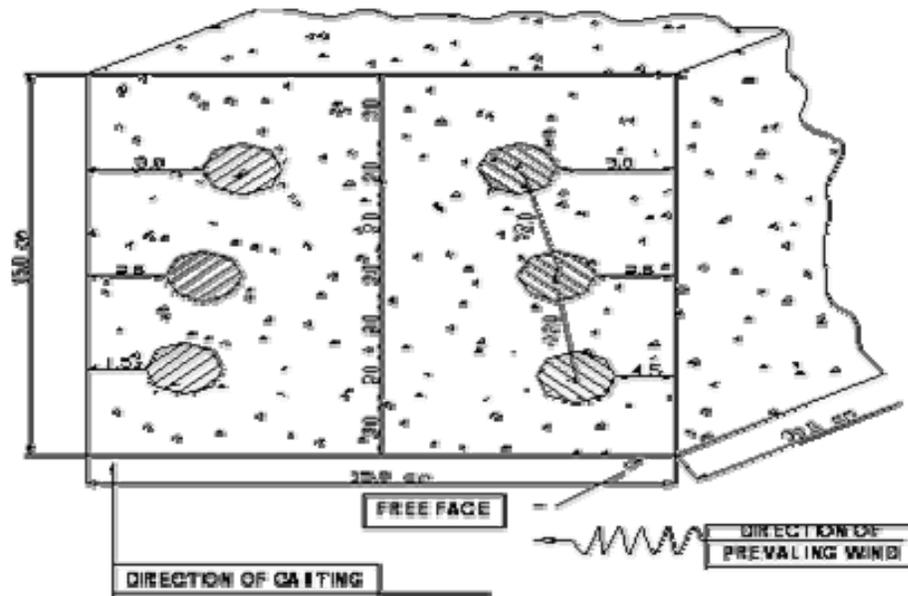
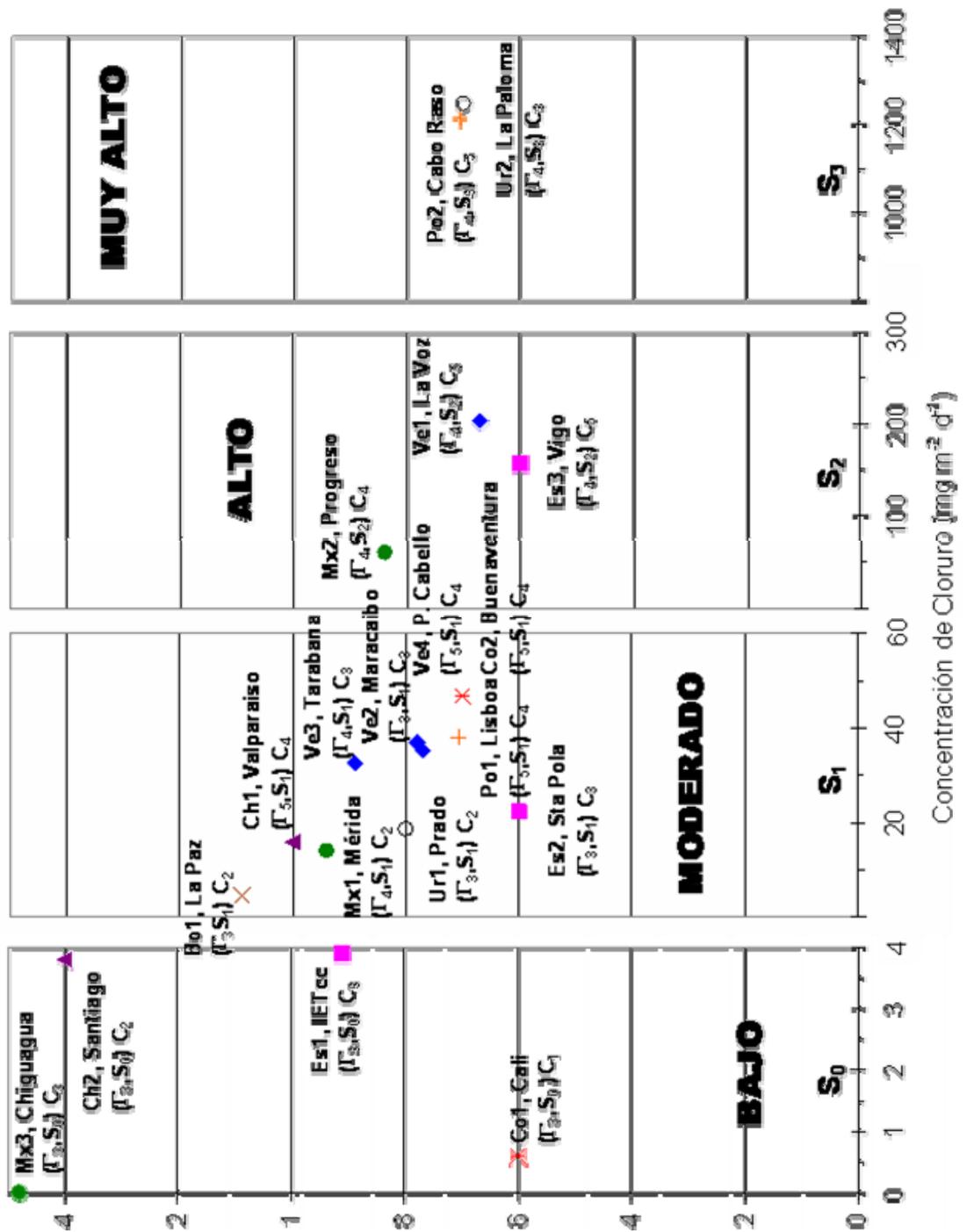Figure 2. Enviromental corrosivity 8ISO 9223)

Figure 3.- Electrochemical Measurements. Potential and Current Density variation during the exposure time in the Marine Stations of a) Cabo Raso and b) La Voz, respectively.
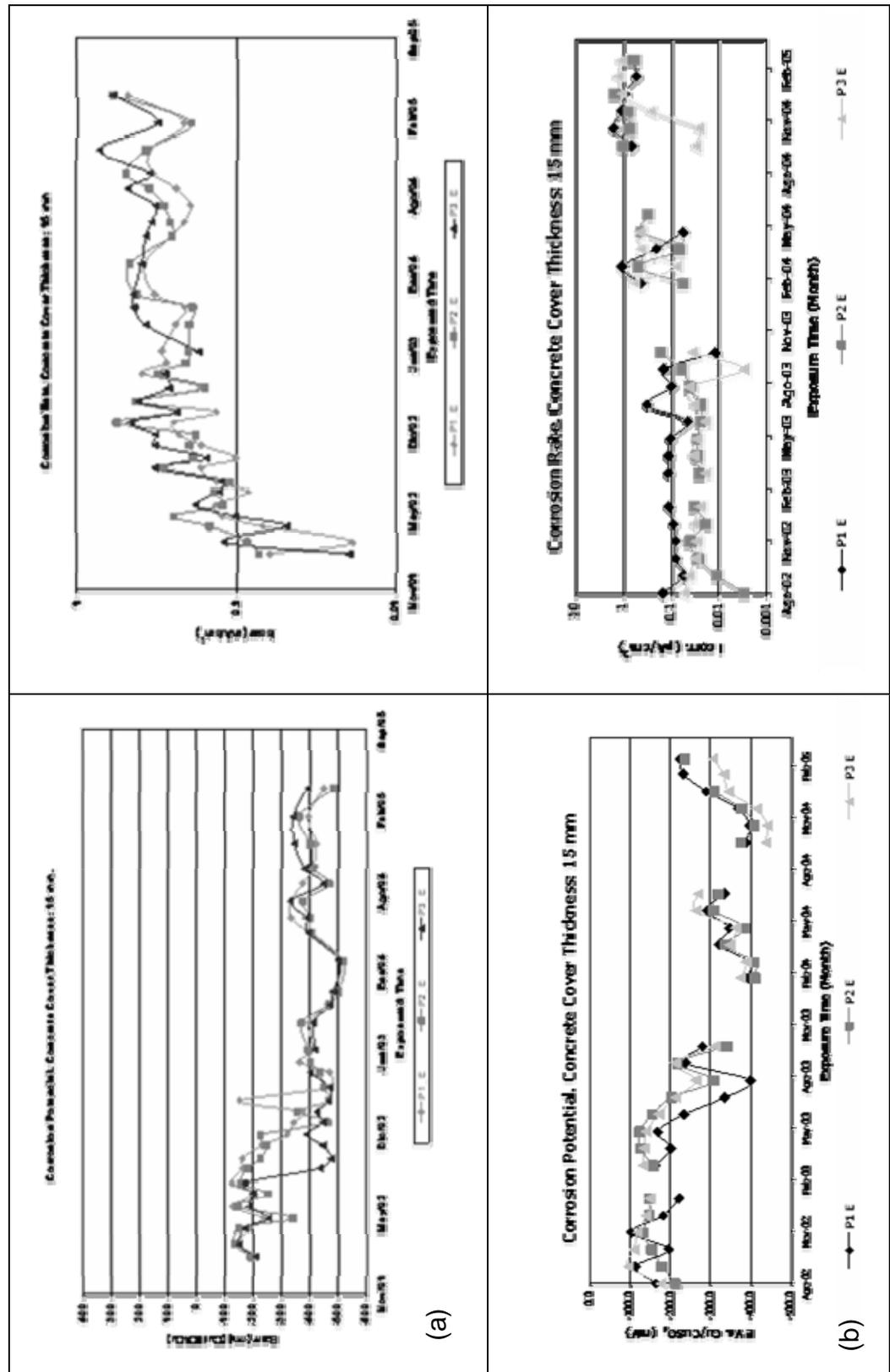
(a)

(b)

Figure 4.- Electrochemical Measurements. Potential and Current Density variation during the exposure time in the Urban Station of Maracaibo.